51527/SAH/T539

WHAT IS CLAIMED IS:

1. An avalanche photodetector comprising an absorption layer, a multiplication region including at least one multiplication layer, and a graded transition region between said absorption layer and said multiplication region, said graded transition region including a graded conduction band energy level that produces a gradual change between a first conduction band energy level of said absorption layer and a second conduction band energy level of said multiplication region.

2. The avalanche photodetector as in claim 1, in which a potential energy difference between said absorption layer and said multiplication region, is about 0.475 eV.

3. The avalanche photodetector as in claim 1, in which said graded transition region is formed of a graded-bandgap material having a wider bandgap region closer to said multiplication region and a narrower bandgap region closer to said absorption layer.

4. The avalanche photodetector as in claim 1, in which said graded transition layer is formed of InGaAlAs and said InGaAlAs is a graded bandgap material in which a ratio of at least two cations of said InGaAlAs varies within said graded bandgap material.

5. The avalanche photodetector as in claim 1, in which said graded transition region is formed of In, Ga, Al and As.

6. The avalanche photodetector as in claim 5, in which said absorption layer is formed of InGaAs and in which said multiplication region is composed of two

multiplication layers being an InAlAs multiplication layer disposed closer to said graded transition region and an InGaAlAs multiplication layer disposed further from said graded transition region and further comprising a charge layer formed of InAlAs and interposed between said graded transition region and said InAlAs multiplication layer.

7. The avalanche photodetector as in claim 5, in which said graded transition region is a film having a top facing said absorption layer and a bottom facing said multiplication region and a ratio of Al:Ga varies gradually such that Ga concentration is maximized and Al concentration is minimized at said top, and Ga concentration is minimized and Al concentration is maximized at said bottom.

8. The avalanche photodetector as in claim 7, in which said graded transition region comprises essentially InGaAs at said top and InAlAs at said bottom.

9. The avalanche photodetector as in claim 1, in which said graded transition region is a quarternary material.

10. The avalanche photodetector as in claim 9, in which said quarternary material includes at least two cations including molar fractions that vary throughout said quarternary material to effectuate a graded bandgap material.

11. The avalanche photodetector as in claim 1, in which said graded transition region includes a thickness and an un-biased effective electric field is defined as the difference of said first conduction band energy level and said second conduction band energy level divided by said thickness, and further comprising an applied bias applied across said avalanche photodetector, said thickness and said

applied bias chosen such that said applied bias exceeds said un-biased effective electrical field by at least 20 kV/cm.

12. The avalanche photodetector as in claim 1, in which said graded transition region includes a thickness within the range of 500Å to 0.4 microns.

13. The avalanche photodetector as in claim 1, further comprising a charge layer having essentially said second conduction band energy level and interposed between said graded transition region and said multiplication region, said charge layer including dopant impurities therein to produce an abrupt step in electrical field strength.

14. The avalanche photodetector as in claim 1, further comprising a power supply coupled to said avalanche photodetector and capable of providing a bias thereacross.

15. An absorption region of an avalanche photodetector, said absorption region having a top and a bottom and including a P-type dopant impurity therein, such that

$$\frac{k_B T}{q}\frac{\partial}{\partial x}\ln(N_A(x)) \geq 3kV/cm$$

in which k_B is the Boltzmann constant, T represents operating temperature of said photodetector in degrees Kelvin, q is the fundamental unit of charge, N_A represents concentration of said P-type dopant impurity, and x represents distance from one of said top and said bottom.

16. The absorption region of an avalanche photodetector as in claim 15, in which said absorption region is a layer of InGaAs.

17. The absorption region of an avalanche photodetector as in claim 15, wherein said P-type dopant impurity comprises one of zinc and carbon.

18. The absorption region of an avalanche photodetector as in claim 15, further including a multiplication layer disposed beneath said absorption region and in which said x represents distance from said bottom.

19. An avalanche photodetector comprising an absorption layer having a top and a bottom, and a multiplication region disposed facing said bottom and including at least one multiplication layer, said absorption layer including a P-type impurity therein, and a P-type impurity concentration gradient such that said P-type impurity concentration decreases from said top to said bottom.

20. The avalanche photodetector as in claim 19, wherein said absorption layer is formed of InGaAs.

21. The avalanche photodetector as in claim 19, wherein said P-type impurity comprises one of zinc and carbon.

22. The avalanche photodetector as in claim 19, in which said P-type impurity concentration gradient satisfies

$$\frac{k_B T}{q}\frac{\partial}{\partial x}\ln(N_A(x)) \geq 3kV/cm$$

in which k_B is the Boltzmann constant, T represents operating temperature of said photodetector in degrees Kelvin, q is the fundamental unit of charge, N_A represents said P-type impurity concentration, and x represents distance from said bottom.

23. The avalanche photodetector as in claim 19, in which said absorption layer includes a thickness within the range of 0.1 to 0.6 microns.

24. The avalanche photodetector as in claim 19, further comprising a charge layer interposed between said absorption layer and said multiplication region and formed of substantially the same material as a first multiplication layer disposed adjacent said charge layer, said charge layer including dopant impurities therein.

25. The avalanche photodetector as in claim 20, further comprising a charge layer formed of InAlAs and interposed between said absorption layer and said multiplication region, said multiplication region composed of an InAlAs multiplication layer disposed adjacent said charge layer and an InGaAlAs multiplication layer.

26. The avalanche photodetector of claim 25, in which said P-type impurity concentration gradient satisfies

$$8kV/cm \geq \frac{k_B T}{q}\frac{\partial}{\partial x}\ln(N_A(x)) \geq 3kV/cm$$

in which k_B is the Boltzmann constant, T represents operating temperature of said photodetector in degrees Kelvin, q is the fundamental unit of charge, N_A represents said P-type impurity concentration, and x represents distance from said bottom.

27. The avalanche photodetector as in claim 19, further comprising a graded transition region disposed between said absorption layer and said multiplication region, said graded transition region being a graded-bandgap material, including a graded conduction band energy level that produces a gradual change between a first conduction band energy level of said absorption layer and a second conduction band energy level of said multiplication region.

28. An avalanche photodetector comprising an absorption layer, a multiplication region and a charge layer disposed between said multiplication region and said absorption layer, said multiplication region consisting of only two multiplication layers including a first multiplication layer formed of a relatively wide bandgap material and disposed closer to said absorption layer and a second multiplication layer formed of a relatively narrow bandgap material and disposed further from said absorption layer, said first multiplication layer and said second multiplication layer having a combined thickness of at least 0.1 microns.

29. The avalanche photodetector as in claim 28, wherein said first multiplication layer is formed of substantially the same material as said charge layer.

30. The avalanche photodetector as in claim 29, wherein said charge layer includes dopant impurities therein to produce an abrupt step in electric field strength.

31. The avalanche photodetector as in claim 28, wherein said charge layer and said first multiplication layer are formed of InAlAs, said second multiplication layer is formed of InGaAlAs, and said absorption layer is formed of InGaAs.

32. The avalanche photodetector as in claim 28, wherein said combined thickness is at least 0.2 microns and a charge layer thickness is no greater than 10% of said combined thickness.

33. The avalanche photodetector as in claim 28, further comprising a graded transition region disposed between said absorption layer and said charge layer, said graded transition region being a graded-bandgap material including a graded conduction band energy level that produces a gradual change between a first conduction band energy level of said absorption layer and a second conduction band energy level of said first multiplication layer.

34. The avalanche photodetector as in claim 28, in which said absorption layer includes a top and a bottom facing said multiplication region and includes a P-type impurity therein, said absorption layer including a P-type impurity concentration gradient decreasing from said top to said bottom.

35. The avalanche photodetector as in claim 28, in which each of said first multiplication layer and said second multiplication layer includes a thickness of at least 0.1 micron.